

CLAIMS

What is claimed is:

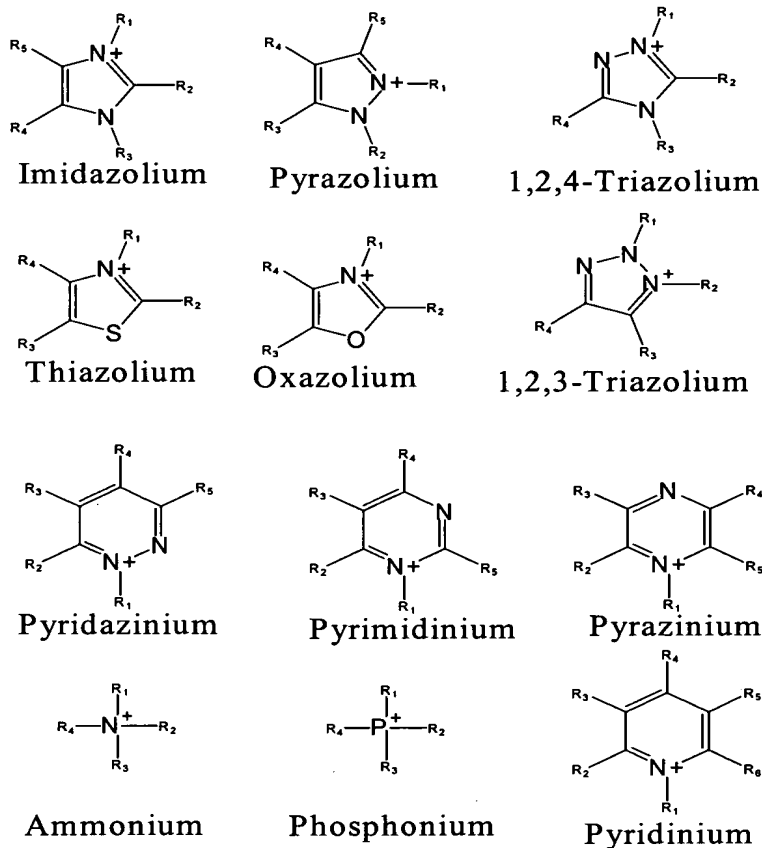
1. A method of forming a lithium ion battery having  
5 reduced flammability, said method comprising the steps  
of:

assembling a battery skeleton comprising a carbon  
anode electrode, a cathode electrode, a separator and  
packaging for said battery;

- 10 forming a solid electrolyte interphase on said  
carbon anode using a first electrolyte;

- combining a lithium metal salt and an organic  
solvent and mixing with said combination an organic  
cation salt to form an organic cation salt electrolyte,  
15 wherein said cation in said salt is selected from the  
group consisting of:

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wherein R<sub>1</sub>, R<sub>2</sub>, R<sub>3</sub>, R<sub>4</sub>, R<sub>5</sub>, and R<sub>6</sub> are either H; or F; or separate alkyl groups of from 1 to 15 carbon atoms, respectively; or two of said separate alkyl groups are joined together to constitute a unitary alkylene radical of from 2 to 6 carbon atoms forming a ring structure converging on N; or separate phenyl groups, and

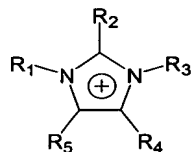
wherein said alkyl groups, said unitary alkylene radical or said phenyl groups are optionally substituted;

replacing said first electrolyte with said organic cation salt electrolyte; and

sealing said battery.

2. A lithium ion battery made by the method of claim 1.

5 3. The method of claim 1, wherein, in said combining step, said cation in said organic cation salt is



wherein R<sub>4</sub> and R<sub>5</sub> are not equal to H.

10 4. The method of claim 1, wherein, in said combining step, said organic cation salt is added at a concentration of greater than 0.5 M.

15 5. The method of claim 1, wherein, in said combining step, said organic cation salt is added at a concentration of greater than 1 M.

20 6. The method of claim 1, wherein, in said combining step, said organic solvent is selected from the group consisting of organic carbonates, gamma-butyrolactone, methyl acetate, ethyl acetate, methyl formate, sulfolane, methylsulfolane, diethyl ether, methyl ethyl ether, tetrahydrofuran, 2-methyltetrahydrofuran, 1,3-dioxolane, nitromethane, acetonitrile, dimethylformamide, dimethylacetamide, dimethylsulfoxide, 25 benzonitrile and combinations thereof.

7. The method of claim 1, wherein, in said combining step, said carbonate solvent is selected from the group

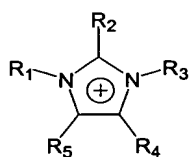
consisting of ethylene carbonate, propylene carbonate,  
butylene carbonate, dimethyl carbonate, diethyl  
carbonate, ethyl methyl carbonate, ethyl propyl  
carbonate, propyl methyl carbonate, butyl methyl  
5 carbonate, vinylene carbonate and combinations thereof.

8. The method of claim 1, further comprising the step  
of increasing the viscosity of said organic cation salt  
electrolyte in said battery with the addition of a  
10 binder.

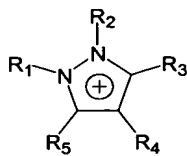
9. The method of claim 1, wherein, in said combining  
step, an additive selected from the group consisting of  
vinylene carbonate, an alkyl phosphonate and an alkyl  
15 nitrite, all at a concentration less than 0.5 M, is  
further included in said mixture.

10. An electrolyte having reduced flammability, said  
electrolyte comprising:

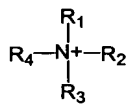
20 an organic cation salt, wherein said cation in said  
salt is selected from the group consisting of:



wherein R<sub>1</sub>, R<sub>2</sub>, R<sub>3</sub>, R<sub>4</sub>, and R<sub>5</sub> are not



equal to H, wherein R<sub>1</sub> and R<sub>2</sub> are not

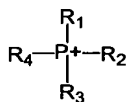


equal to H, and wherein R<sub>1</sub>, R<sub>2</sub>, R<sub>3</sub>, and  
25 R<sub>4</sub> are not equal to H;

an organic solvent; and  
a metal salt comprising an alkali or alkaline earth metal cation.

- 5 11. An electrolyte having reduced flammability, said electrolyte comprising:

an organic cation salt, wherein said cation in said salt is:



wherein  $R_1$ ,  $R_2$ ,  $R_3$ , and  $R_4$  are not equal

- 10 to H;

an organic solvent; and  
a metal salt comprising an alkali or alkaline earth metal cation.

- 15 12. The electrolyte of claim 10 or claim 11, wherein said cation in said metal salt is selected from the group consisting of  $Li^+$ ,  $Na^+$ ,  $K^+$ ,  $Mg^{++}$ ,  $Ca^{++}$ ,  $Al^{+++}$  and combinations thereof.

- 20 13. An electrochemical cell comprising  
an anode;  
a cathode; and  
the electrolyte of claim 10 or claim 11.

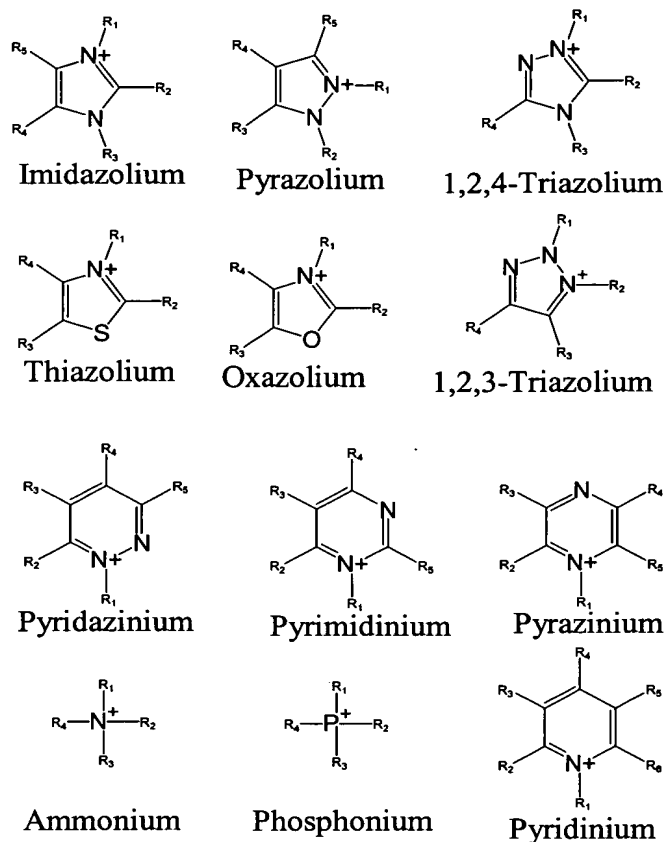
- 25 14. A battery comprising the electrochemical cell of claim 13.

15. The electrolyte of claim 10 or claim 11 wherein said organic solvent is selected from the group

consisting of organic carbonates, gamma-butyrolactone, methyl acetate, ethyl acetate, methyl formate, sulfolane, methylsulfolane, diethyl ether, methyl ethyl ether, tetrahydrofuran, 2-methyltetrahydrofuran, 1,3-  
5 dioxolane, nitromethane, acetonitrile, dimethylformamide, dimethylacetamide, dimethylsulfoxide, benzonitrile and combinations thereof.

16. The electrolyte of claim 10 or claim 11 wherein  
10 said carbonate solvent is selected from the group consisting of ethylene carbonate, propylene carbonate, butylene carbonate, dimethyl carbonate, diethyl carbonate, ethyl methyl carbonate, ethyl propyl carbonate, propyl methyl carbonate, butyl methyl  
15 carbonate, vinylene carbonate and combinations thereof.

17. An electrolyte having reduced flammability, said electrolyte comprising:  
an organic cation salt at a concentration of  
20 greater than or equal to 0.75 M, wherein said cation in said salt is selected from the group consisting of:



wherein  $R_1$ ,  $R_2$ ,  $R_3$ ,  $R_4$ ,  $R_5$ , and  $R_6$  are either H; or F; or separate alkyl groups of from 1 to 15 carbon atoms, respectively; or two of said separate alkyl groups are joined together to constitute a unitary alkylene radical of from 2 to 6 carbon atoms forming a ring structure converging on N; or separate phenyl groups, and

wherein said alkyl groups, said unitary alkylene radical or said phenyl groups are optionally substituted;  
an organic solvent; and

a metal salt comprising an alkali or alkaline earth metal cation.

18. The electrolyte of claim 17 wherein said cation in  
5 said metal salt is selected from the group consisting of  
 $\text{Li}^+$ ,  $\text{Na}^+$ ,  $\text{K}^+$ ,  $\text{Mg}^{++}$ ,  $\text{Ca}^{++}$ ,  $\text{Al}^{+++}$  and combinations thereof.

19. An electrochemical cell comprising  
an anode;  
10 a cathode; and  
the electrolyte of claim 17.

20. A battery comprising the electrochemical cell of  
claim 19.

21. The electrolyte of claim 17, wherein said organic  
solvent is selected from the group consisting of organic  
carbonates, gamma-butyrolactone, methyl acetate, ethyl  
acetate, methyl formate, sulfolane, methylsulfolane,  
20 diethyl ether, methyl ethyl ether, tetrahydrofuran, 2-  
methyltetrahydrofuran, 1,3-dioxolane, nitromethane,  
acetonitrile, dimethylformamide, dimethylacetamide,  
dimethylsulfoxide, benzonitrile and combinations  
thereof.

22. The electrolyte of claim 17 wherein said carbonate  
solvent is selected from the group consisting of  
ethylene carbonate, propylene carbonate, butylene  
carbonate, dimethyl carbonate, diethyl carbonate, ethyl  
30 methyl carbonate, ethyl propyl carbonate, propyl methyl



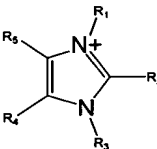
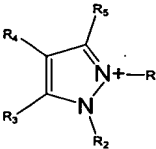
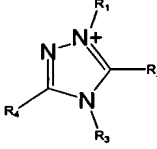

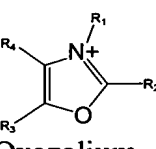
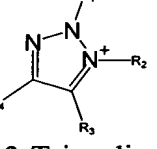
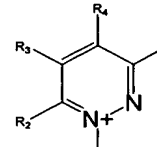
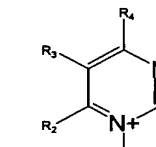
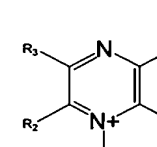
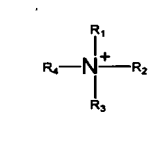
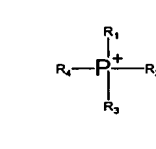
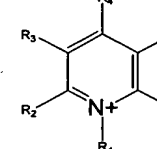
carbonate, butyl methyl carbonate, vinylene carbonate and combinations thereof.

23. The electrolyte of anyone of claims 10, 11 or 17,  
5 wherein the viscosity of said electrolyte is increased with the addition of a binder.

24. The electrolyte of anyone of claims 10, 11 or 17,  
10 further comprising an additive selected from the group consisting of vinylene carbonate, an alkyl phosphonate and an alkyl nitrite, having a concentration less than 0.5 M.

25. A gel polymer electrolyte having reduced  
15 flammability, said gel polymer electrolyte comprising:

an organic cation salt, wherein said cation in said salt is selected from the group consisting of:

		
Imidazolium	Pyrazolium	1,2,4-Triazolium
		
Thiazolium	Oxazolium	1,2,3-Triazolium
		
Pyridazinium	Pyrimidinium	Pyrazinium
		
Ammonium	Phosphonium	Pyridinium

wherein R<sub>1</sub>, R<sub>2</sub>, R<sub>3</sub>, R<sub>4</sub>, R<sub>5</sub>, and R<sub>6</sub> are either H; or F; or separate alkyl groups of from 1 to 15 carbon atoms, respectively; or two of said separate alkyl groups are joined together to constitute a unitary alkylene radical of from 2 to 6 carbon atoms forming a ring structure converging on N; or separate phenyl groups, and

wherein said alkyl groups, said unitary  
alkylene radical or said phenyl groups are  
optionally substituted;

an organic solvent;

a metal salt comprising an alkali or alkaline earth metal cation; and

one or more polymers selected from the group consisting of acrylate polymer and fluoropolymer.

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26. The gel polymer electrolyte of claim 25, wherein said acrylate polymer is a methacrylate polymer with at least 1 monomer copolymerizable to methylmethacrylate.

10 27. The gel polymer electrolyte of claim 25, wherein  
said one or more polymers consist of a mixture of two or  
more polymers.

28. The gel polymer electrolyte of claim 25, wherein  
15 said fluoropolymer is poly(vinylene)fluoride.

29. The gel polymer electrolyte of claim 26, wherein said monomer is selected from the group consisting of styrene-containing monomers, cyano-group-containing monomers, unsaturated carboxylic acids, acid anhydrides, esters, vinyl halides, vinylene halide monomers, vinyl esters, vinyl ethers and dienes.

30. The gel polymer electrolyte of claim 29, wherein  
25 said monomer is selected from the group consisting of  
styrene, divinylbenzene, methacrylonitrile, acrylic  
acid, sodium acrylate, maleic anhydride, methyl  
methacrylate, ethyl acrylate, propyl acrylate,  
tetra(ethylene glycol) diacrylate, hydroxyethyl  
30 methacrylate, vinyl chloride, vinyl fluoride, vinyl  
bromide, vinylene chloride, vinylene fluoride, vinylene

bromide, vinyl formate, vinyl acetate, vinyl group-containing acids compounds or their salts, anhydrides or derivatives, methyl vinyl ether, butadiene, isoprene and chloroprene.

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31. The gel polymer electrolyte of claim 25, wherein said solvent is selected from the group consisting of organic carbonates, gamma-butyrolactone, methyl acetate, ethyl acetate, methyl formate, sulfolane, methylsulfolane, diethyl ether, methyl ethyl ether, tetrahydrofuran, 2-methyltetrahydrofuran, 1,3-dioxolane, nitromethane, acetonitrile, dimethylformamide, dimethylacetamide, dimethylsulfoxide, benzonitrile and combinations thereof.

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32. The gel polymer electrolyte of claim 31, wherein said organic carbonate is selected from the group consisting of ethylene carbonate, propylene carbonate, butylene carbonate, dimethyl carbonate, diethyl carbonate, ethyl methyl carbonate, ethyl propyl carbonate, propyl methyl carbonate, butyl methyl carbonate, vinylene carbonate and combinations thereof.

33. The gel polymer electrolyte of claim 25, wherein said cation in said metal salt is selected from the group consisting of  $\text{Li}^+$ ,  $\text{Na}^+$ ,  $\text{K}^+$ ,  $\text{Mg}^{++}$ ,  $\text{Ca}^{++}$ ,  $\text{Al}^{+++}$  and combinations thereof.

34. The gel polymer electrolyte of claim 25, wherein said anion in said metal salt is selected from the group

consisting of  $I^-$ ,  $Br^-$ ,  $SCN^-$ ,  $BF_4^-$ ,  $PF_6^-$ ,  $AsF_6^-$ ,  $CF_3SO_2^-$ ,  
( $CF_3SO_2$ ) $_2N^-$ , ( $CF_3CF_2SO_2$ ) $_2N^-$ , and ( $CF_3SO_2$ ) $_3C^-$ .

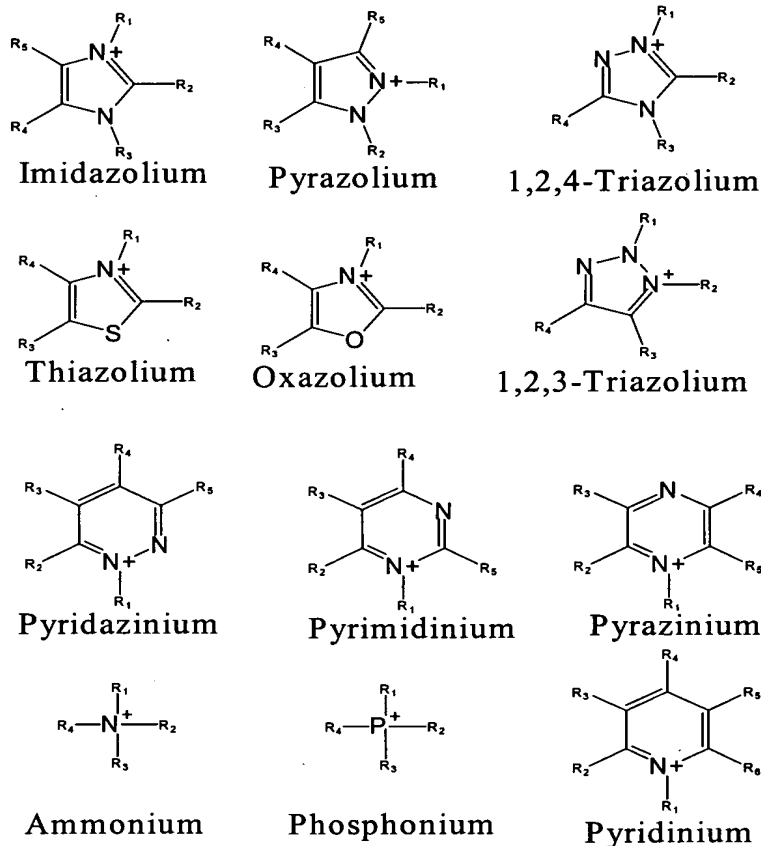
35. The gel polymer electrolyte of claim 25 further  
5 comprising a saturated or unsaturated cyclic or acyclic  
organic carbonate or lactone.

36. The gel polymer electrolyte of claim 25 further  
comprising an additive selected from the group  
10 consisting of vinylene carbonate, an alkyl phosphonate  
and an alkyl nitrite, having a concentration less than  
0.5 M.

37. The gel polymer electrolyte of claim 25 wherein  
15 said organic cation salt is an peralkylated imidazolium  
cation in combination with various anions.

38. A method for the production of a gel polymer  
electrolyte comprising the steps of:

20 combining to form a mixture an organic solvent, one  
or more polymers selected from the group consisting of  
acrylate polymers and fluoropolymers, a metal salt  
comprising an alkali or alkaline earth metal cation, and  
an organic cation salt, wherein said cation in said salt  
25 is selected from the group consisting of:



wherein R<sub>1</sub>, R<sub>2</sub>, R<sub>3</sub>, R<sub>4</sub>, R<sub>5</sub>, and R<sub>6</sub> are either H; or F; or separate alkyl groups of from 1 to 15 carbon atoms, respectively; or two of said separate alkyl groups are joined together to constitute a unitary alkylene radical of from 2 to 6 carbon atoms forming a ring structure converging on N; or separate phenyl groups, and

wherein said alkyl groups, said unitary alkylene radical or said phenyl groups are optionally substituted; and processing said mixture.

39. The method of claim 38, wherein said processing step is selected from the group consisting of:

a. heating said mixture at approximately 100°C to yield a homogeneous melt, followed by casting and  
5 cooling said melt,

b. exposing said mixture to UV-light initiated polymerization, said mixture also containing a photoinitiator, and

c. exposing said mixture to thermal initiated  
10 polymerization at approximately 60°C.